

Project 3: Bio-Inspired Optimization of the Multiple Traveling Salesman Problem

Area Coordinator:

Dr. Kelly Cohen
Professor of Aerospace Engineering & Engineering Mechanics
Department of Aerospace Engineering and Engineering Mechanics
University of Cincinnati
Cincinnati, OH 45221-0070
Office: 735 Rhodes Hall
E-Mail: Kelly.Cohen@uc.edu
Phone: 513-556-3523

Sub-Area Coordinator:

Dr. Jeff Kastner
Assistant Professor Educator
Department of Engineering Education
University of Cincinnati
Cincinnati, OH 45221-0074
Office: 881 Rhodes Hall,
E-Mail: Jeffrey.Kastner@uc.edu
Phone: 513-556-0027

Graduate Research Assistant:

Mr. Anoop Sathyan
Ph.D. Student in Aerospace Engineering
Office: Old Chem Building, Room 512
E-Mail: sathyaap@mail.uc.edu
Phone: 217-816-4309

Project Summary

Context: This research topic is inspired by one of the NAE grand *challenges* for engineering, namely, “Reverse-Engineer of the Brain”. As engineering solutions become more large-scale and complex, the desire is for machines to emulate a human’s ability to adapt quickly and effectively. It is anticipated that the area of autonomy and control is a major research area for all unmanned systems, whether military, commercial, or academic in origin [1]. Furthermore, adaptability and learning from past experience are still at early stages of capability. Intelligent systems technologies are enabling air and space missions to exhibit an increased level of autonomy, to be more adaptable, to learn, and to have improved performance. Within the framework of this REU program, we will utilize heuristics, based on human intuition and using intelligent systems technologies such as fuzzy logic and genetic algorithms, to develop new and unique approaches to large-scale combinatorial optimization problems [2]. A sub-class of very famous problems is referred to as the traveling salesman problem (**TSP**) which involves finding the shortest path, and has applications in the several diverse areas such as aerospace, logistics, genetics, manufacturing, telecommunications, and neuroscience [3].

Research Goal & Plan: In this project we will study the **basic** principles of **decision making** with an emphasis on **bio-inspired optimization** techniques. The idea is to **empower and enable teachers** to **introduce research concepts** in the **classroom** within the engineering design challenge of improving thinking in terms of getting students “**the best bang for their buck**”.

We will be using the “Traveling Salesman Problem” as a benchmark for learning optimization. The TSP is defined in the following way: a traveling salesman has to visit a certain list of cities, whose locations are known, such that each city is visited exactly once, while minimizing the total cost of travel, where cost is usually defined in terms of distance, time, or price, with fixed costs associated with travel between each pair of cities (see **Figure 1**). Obtaining an optimal solution to high order TSPs takes time

using the iterative computational approaches available in the state-of-the-art [3]. In many practical applications, we require “multiple salesman” (see **Figure 2**) which leads the “Multiple Travelling Salesman Problem” or MTSP [4]. In this effort we will investigate the applicability of a newly developed mix of K-means clustering and genetic algorithms to provide a computationally efficient near optimal solution to a MTSP. The quality and computational speed of the solution will be compared with that obtained using state-of-the-art genetic algorithm available on MATLAB Central. Monte Carlo simulations will be utilized to statistically validate the robustness of the proposed approach.



Figure 1: The TSP Solution for a 20-City Problem Having 6.1×10^{16} Permutations (from <http://www.solver.com/solver-platform-sdk-source-code-examples>)

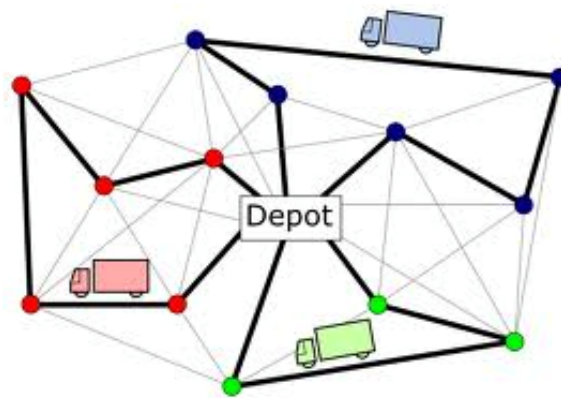


Figure 2: The Multiple TSP (from <http://www.rcasts.com/2010/11/any-r-packages-to-solve-vehicle-routing.html>)

Research Content Training: The MTSP class of problems will be discussed and connected to: the vast number of applications; merits of MTSP; the underlying computational challenges; and current state-of-the-art approaches. Introduction to fuzzy logic decision-making systems; use of the MATLAB toolbox and important engineering applications; and introduction to Monte Carlo simulations with the rationale, underlying statistical basis, and use in the industry will be provided. A field trip to the Air Force Museum at Wright Patterson Air Force Base in Dayton, OH will focus on Aerospace Engineering applications.

Facilities to be Used: The research will be conducted at the UC’s Most Aero Labs (<http://most-aero.uc.edu/>). The effort is computational in nature and will be conducted on the desk-top PC’s in the lab.

Ideas for Classroom Implementation: A classroom math unit will constitute the study of permutations and combinations possible in MTSP class of problems and using logic, heuristics, and geometric considerations to find the minimum tours. Clustering techniques will be discussed and their importance as a unsupervised machine learning classification tool. The first activity will try to cluster a bunch of geographically distributed targets into a series of sub-tours depending on the number of “salesman”. The second activity will require developing of the shortest sub-tour. The faculty mentors and

the Graduate Research Assistant will: (i) visit the teacher's class to assess the effectiveness of the unit plan developed and to internalize lessons for improvement of the RET learning experience; and (ii) host the teacher's class to visit MOST AERO labs at UC to get an overview of the research applications explored by the graduate student research team working in the area of emulating human reasoning using ruled based decision making as well as bio-inspired approaches top large scale combinatorial optimization problems.

References Cited

1. Department of Defense. (2007). Unmanned Systems Roadmap, 2007-2032. Available online at <http://www.fas.org/irp/program/collect/usroadmap2007.pdf> [accessed 18 December 2008].
2. Korte, B., and Vygen, J. (2008). "Combinatorial Optimization – Theory and Application," *Algorithms and Combinatorics*, 4th Edition, Vol. 21, Springer-Verlag Berlin Heidelberg.
3. Applegate, D. L., Bixby, R. E., Chvatal, V., and Cook, W. J. (2006). *The Traveling Salesman Problem – A Computational Study*. New Jersey: Princeton Series in Applied Mathematics, Princeton University Press.
4. Sathyan, A., Ernest, N., and Cohen, K., "An Efficient Genetic Fuzzy Approach to UAV Swarm Routing", *Unmanned Systems*, April 2016, Vol. 04, No. 2, pp. 117-127.